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THE DIMINIODE: A RESEARCH
AND DEVELOPMENT TOOL
FOR NUCLEAR THERMIONICS

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THE DIMINIODE: A RESEARCH AND DEVELOPMENT TOOL FOR NUCLEAR THERMIONICS

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SUMMARY

Diminiodes are fixed- or variable-gap cesium diodes with plane miniature emitters and guarded collectors. In addition to smallness, their relative advantages are simplicity, precision, ease of fabrication, interchangeability of parts, cleanliness, full instrumentation, ruggedness, and economy. With diminiodes and computers used in thermionic performance mapping, a thorough electrode screening program becomes practical.

A DIFFERENT PLANAR DIODE PROGRAM

Nuclear thermionics requires emitters that give greater currents and collectors that yield higher voltages. Better electrodes mean wider incore design margins - and perhaps another look at the out-of-core diode (refs. 1 to 6). So a program to screen promising emitters and collectors is necessary.

Unfortunately, traditional research methods militated against such intensive performance testing. But computer techniques broke these barriers with massive, economical processing of cesium-diode output data (refs. 7 to 13). That left the question of the research converter itself, and the diminiode (fig. 1) developed as one answer: The concept began with two (di) miniature (mini) electrodes (ode), which could come from easily grown single crystals or other little pieces of rare materials. Relative to conventional research diodes, the diminiode is small, simple, easy to machine and assemble, rugged, interchangeable, reusable, and economical. The design also stresses effective instrumentation and clean, efficient processing (refs. 14 and 15, the appendix, and figs. 2 to 5).

Used with a computer facility, the diminiode yields thermionic performance maps of greatly improved quality, quantity, and economy.

THE DIMINIODE IN DETAIL

As figure 1 shows, the diminiode stands on a solid laminal cylinder, nearly 3 centimeters long and almost 2 centimeters in diameter. This base comprises three concentric conductors (niobium, 1 percent zirconium) bonded together with intervening annuli of insulation (aluminum oxide). Elements like this for three diminiodes result from high-temperature, high-pressure autoclaving of the package indicated in figure 2. The rugged lamination obviates fragile metal-to-ceramic seals like those in traditional cesium diodes. But it also connects the electrodes to appropriate junctions through low-resistance electric paths, provides uniform thermal conduction to the collector and guard, and supports the diminiode in solid precision.

Atop the diminiode base, diffusion bonds or high-temperature brazes hold the collector and guard. These electrodes are both cut from the same material and have identical orientations if possible. Their diameters in centimeters are 0.457 for the collector and 0.482 inside, 0.635 outside for the guard. The last diameter corresponds to that of the emitter, which a fusion bond joins to the diminiode cap and electron-bombardment target (tantalum). In turn, this top piece rests on a standard 1.905-centimeter tube (tantalum) attached to the laminal base through precisely machined shoulders for alignment. Joints other than those for the electrodes are electron-beam welds or high-temperature brazes. On the side wall, a 0.635-centimeter tube (tantalum) opens directly on the electrodes. It serves as a high-conductance cesium reservoir after it enables internal degassing and pyrometry.

The previously mentioned black-body holes and thermocouples allow doubly checked thermal measurements: They indicate the temperatures of the emitter, of the collector, guard assembly, and of the cesium reservoir. While electron bombardment heats the emitter, thermal-control coils adjust the temperatures of the guarded collector and the reservoir. Initial designs and final operations call for clamp-on thermal controls, but the indicated absolute contact of brazed-on coils insured the critical first few diminiodes. The coolant tubes around the lamination ground the electron-bombardment target and function as emitter current leads. Electric taps for the collector and guard are the center and second steps at the bottom of the diminiode base.

In the variable-gap version (fig. 1(b)) a simple diaphragm bellows allows changes in electrode spacing. And three sets of small clamps and precision shims maintain the emitter and collector positions.

Although most of the diminiode components are interchangeable, the electrodes are exceptions: Collector, guard combinations, emitters, or both are specific in electrode performance evaluations. So assigning their nominal diameters in no way precludes a wide adaptation of dimensions to accommodate special electrode materials. Otherwise, the prescribed assembly of several parts from the shelf produces another diminiode like the rest - ready for bake-out, calibration, cesium charging, and closure.

VACUUM PROCESSING THE DIMINIODE

To minimize costly time-consuming bake-out cycles, a multipurpose vacuum chamber (fig. 3) facilitates all operations remaining to finish the diminiode. In this chamber following only one pump-down the diminiode made of baked-out components undergoes a final high-temperature degassing, internal and external pyrometry, and fusion sealing after the cesium capsule insertion. The cesium itself is an off-the-shelf component like the other interchangeable parts of diminiodes. It comes in baked-out, brazed-shut, breakable molybdenum vials (refs. 14 and 15, the appendix, and figs. 4 and 5). One of these ampules, a degassed tantalum ball, and a diminiode go into the station before its closure. Then, after the pump-down and degassing at 450°C to below 10^{-8} torr, the diminiode enters the final stages or processing.

As electron bombardment heats the emitter assembly, continual thermal sensing and coolant adjustments bring the diminiode to predetermined bake-out conditions. That state depends on the electrodes, their brazes (if any), and the insulator limit (1400 K). During the temperature rise, the pyrometric cavity in the emitter allows calibrations of the tungsten-lined external black-body hole and the high-temperature thermocouple. The relation between these temperatures depends on the heat-flow rate, too. So the calibrations are comprehensive. Of course, the outer black-body hole then permits emitter-temperature calibrations subsequent to closing the diminiode. This capability enables checking output shifts of the high-temperature thermocouples, adapting a photomultiplier for total-radiation measurements (ref. 8), or using automatic pyrometry.

While the diminiode is at maximum degassing temperatures, electron bombardment of the open end of the reservoir to just below the melting point of the copper-foil insert prepares it for the brazed closure. Following this part of the bake-out, cooling gives a downward calibration to check the upward one.

Next, magnetically pulling the lower pin in the guide tube drops the cesium capsule into the diminiode reservoir. If the pressure rises, another brief bake-out removes contaminants. The same process follows the release of the previously degassed tantalum sphere, which lodges in the funnel opening of the side tube. Then electron bombardment brazes this ball in the end of the reservoir with copper. And the diminiode is complete.

DIMINIODE TESTING

Thermionic performance mapping with a diminiode is not unusual except for the ease of test preparations: The diminiode and its flange base (fig. 1(c)) from the preceding vacuum processing chamber transfer as a unit. So, merely connecting the necessary lines essentially mounts the diminiode in the vacuum test chamber (fig. 6). At the

proper time, pinching the soft tantalum walls of the reservoir in on the molybdenum capsule cracks that ampule and releases the vacuum-packed cesium within the diode. Then after optical alinement, the final closure and pump-down ready the station for operation.

Mockup and prototype tests demonstrated the applicability and controllability of the diminiode (refs. 16 and 17): There emitters ranged from 1500 to 2000 K; collectors, from 750 to 1150 K; and reservoirs, from 550 to 650 K. For these temperature ranges, the maximum thermal variation across the emitter face was less than the resolution of pyrometry (ref. 16). Measurements verifying this uniformity resulted from sighting through an axial bore in a diminiode collector base at five black-body holes equally spaced from one end to the other along a diameter of the cathode surface. These findings indicate in part the effectiveness of the diminiode for performance screening of thermionic electrodes.

Control, acquisition, analysis, and presentation of the diminiode output with computers follow the pattern developed at this laboratory. Because discussions of the test and machine installations and procedures appear elsewhere (refs. 7 and 8), further details seem unwarranted here. But the results are important: From these facilities, in only a few days, come several hundred individual current, voltage curves and power, voltage plots - as well as any desired envelopes (refs. 8 to 11).

COMPUTERS AND DIMINIODES

In summary, computerized performance mapping by itself justifies a thorough evaluation program for promising emitters and collectors. And as the preceding text indicates, the diminiode makes possible the following advantages.

- (1) Wider coverage in electrode screening. (The miniature design accepts emitter and collector diameters less than 0.635 cm - like rare single crystals that are available only in small sizes.)
- (2) Greater electrode economy. (Unusual materials - like rhenium single crystals - are often reasonable in small sizes but exorbitant with larger dimensions.)
- (3) Better electrode alinement. (The design allows precise machining and assembly of the basically rigid parts. Also, being off by the same angle gives less spacing variation with smaller diameters.)
- (4) Less danger of destroying electrode alinement. (The small, rugged diminiode maintains dimensions well. But research diodes with fragile metal-to-ceramic seals and long thin support elements require definite care.)
- (5) Lower overall diode costs. (Because of its few simple parts made mainly with lathe machining and alining, mass production of diminiodes is a definite possibility. Only unusual electrodes require special attention.)

(6) Higher processing efficiency. (The cesium vacuum-packing plant and the multipurpose vacuum processing chamber (for bake-out, calibration, cesium loading, and diode closure) save time and money.)

(7) Cheaper, quicker, more-effective reusable mounts. (Supporting the diminiode on a vacuum-flange insert, with all control and sensing lines included, provides a simple, interchangeable base for processing and testing.)

(8) Cleaner, more-definitive operation. (Higher-temperature bake-outs, limited only by the brazes for the collector, guard assembly and for the heating and cooling lines, mean incomparable cleanliness. This reduces undefined impurity effects.)

(9) Finer determinations of emitter temperatures. (Calibration of a tungsten-lined external black-body cavity against a pyrometric hole in the emitter near its surface assures accurate sensing of emitter temperatures after diminiode closure. Properly defining the emitter temperature is a major problem in diode testing.)

(10) More uniform electrode-surface temperatures. (Mounting the small emitters and guarded collectors in massive bases with good conduction provides excellent thermal distribution and storage. This minimizes temperature variations across the electrodes.)

(11) Simpler, sturdier, more-accurate variable-gap versions.

(12) Easier reuse or rebuilding, if desired.

So the diminiode also encourages electrode screening for cesium converters.

Together (fig. 7), computers and diminiodes mean more and better and less-costly diode-performance maps for nuclear thermionic development.

Lewis Research Center,

National Aeronautics and Space Administration,

Cleveland, Ohio, April 3, 1972,

112-27.

APPENDIX - A CESIUM DISPENSING SYSTEM WITH FREEZE, MELT VALVES

References 14 and 15 show a dispensing train for vacuum packaging cesium. There the injection column ends in a freeze, melt valve near a stainless-steel packless valve (not shown in fig. 5) used to bake out the large volumes of the system. In operation the bellows of the packless valve eventually failed. Rather than replacing that problem with a similar one, two revised designs bring new effectiveness and reliability to the dispensing train.

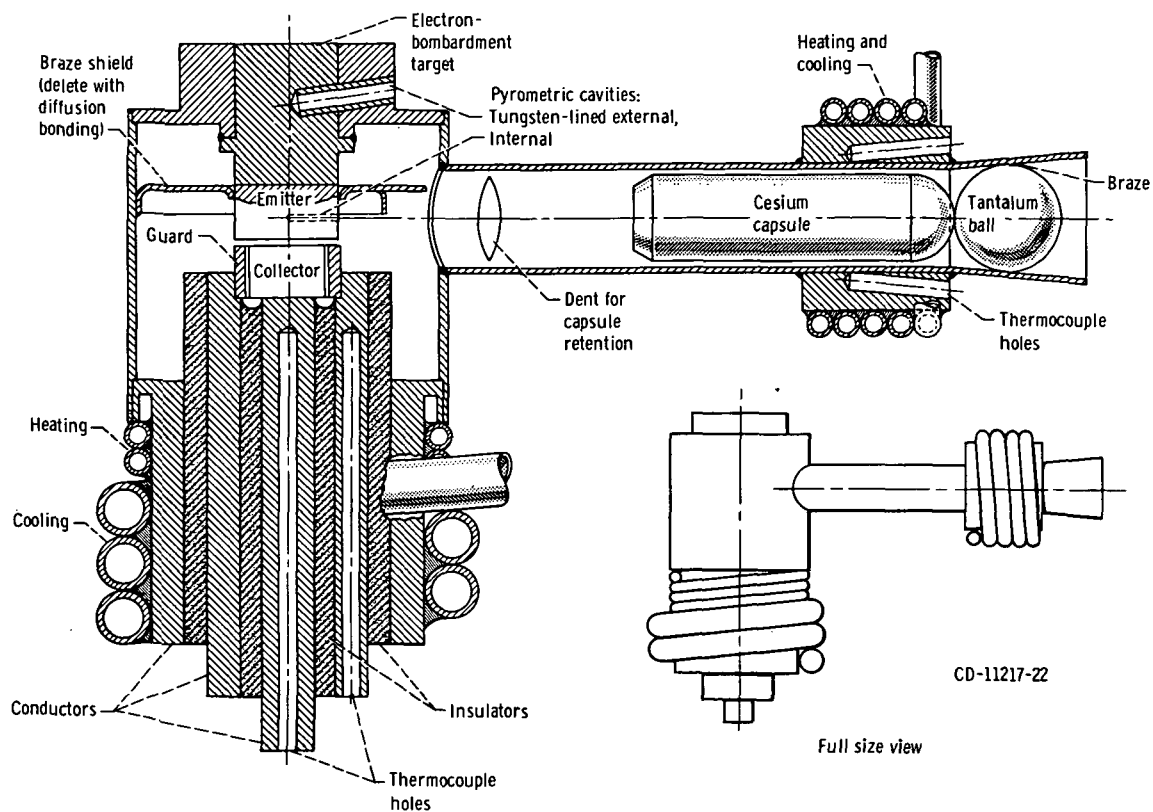
In the first version the bake-out valve is another freeze, melt model—a greatly enlarged form of the dispenser. It terminates a high-conductance path leading directly from the major volume of the feed column to the vacuum chamber for cesium packaging. As a result, degassing the dispensing train is no longer a separate operation. With no cesium in the tubes the system bakes out into the encapsulating station. When the cesium flow begins it shuts both cooled freeze, melt valves. Then while the large one remains closed, the small dispenser controls the cesium as described in reference 15.

The second, simpler design involves increasing the orifice size of the freeze, melt dispenser; minimizing the cesium-entry-tube volume; and eliminating the separate bake-out valve. Now acceptable degassing proceeds through the dispensing valve alone. And the initial throw-away flow of cesium provides a final cleansing before the capsule loading. During operation, adjustment of the incoming liquid temperature and the valve cooling and heating rates effectively produces any dispenser orifice smaller than the empty one - because of peripheral solidification of the cesium. This means that the complete injection-rate range from small separate drops to full streams is still obtainable.

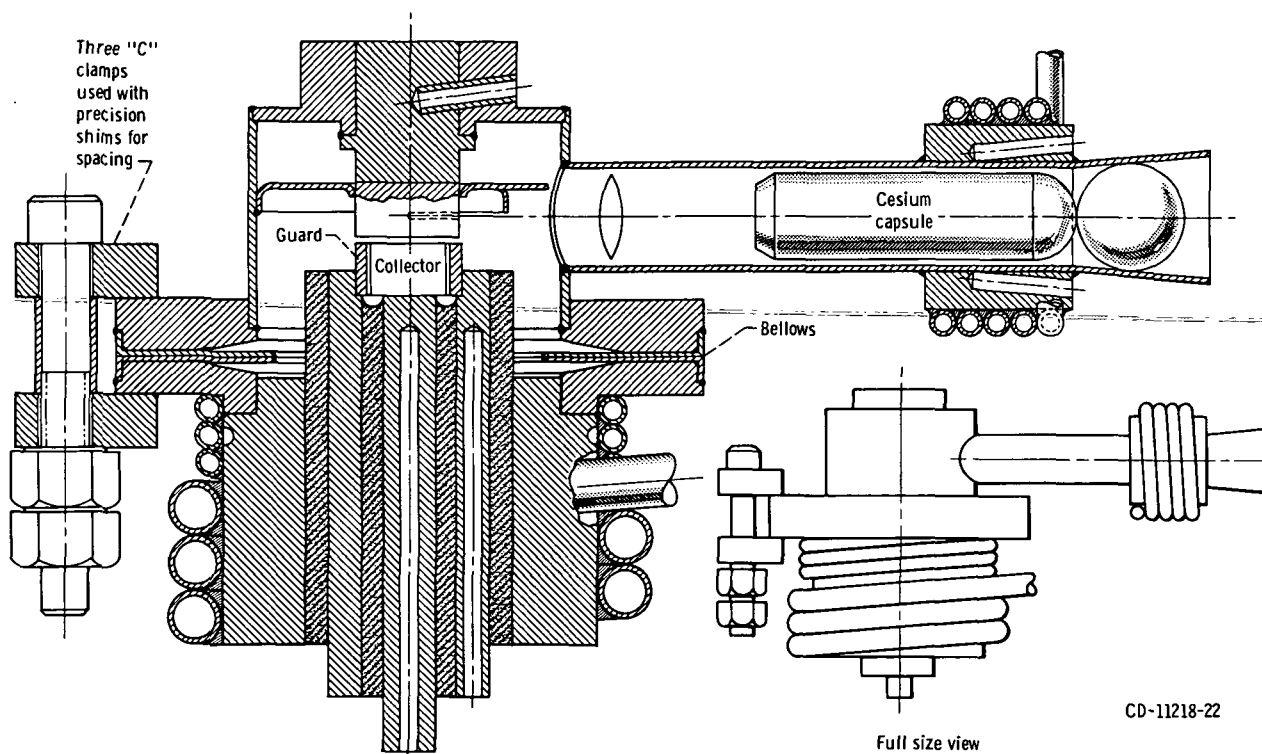
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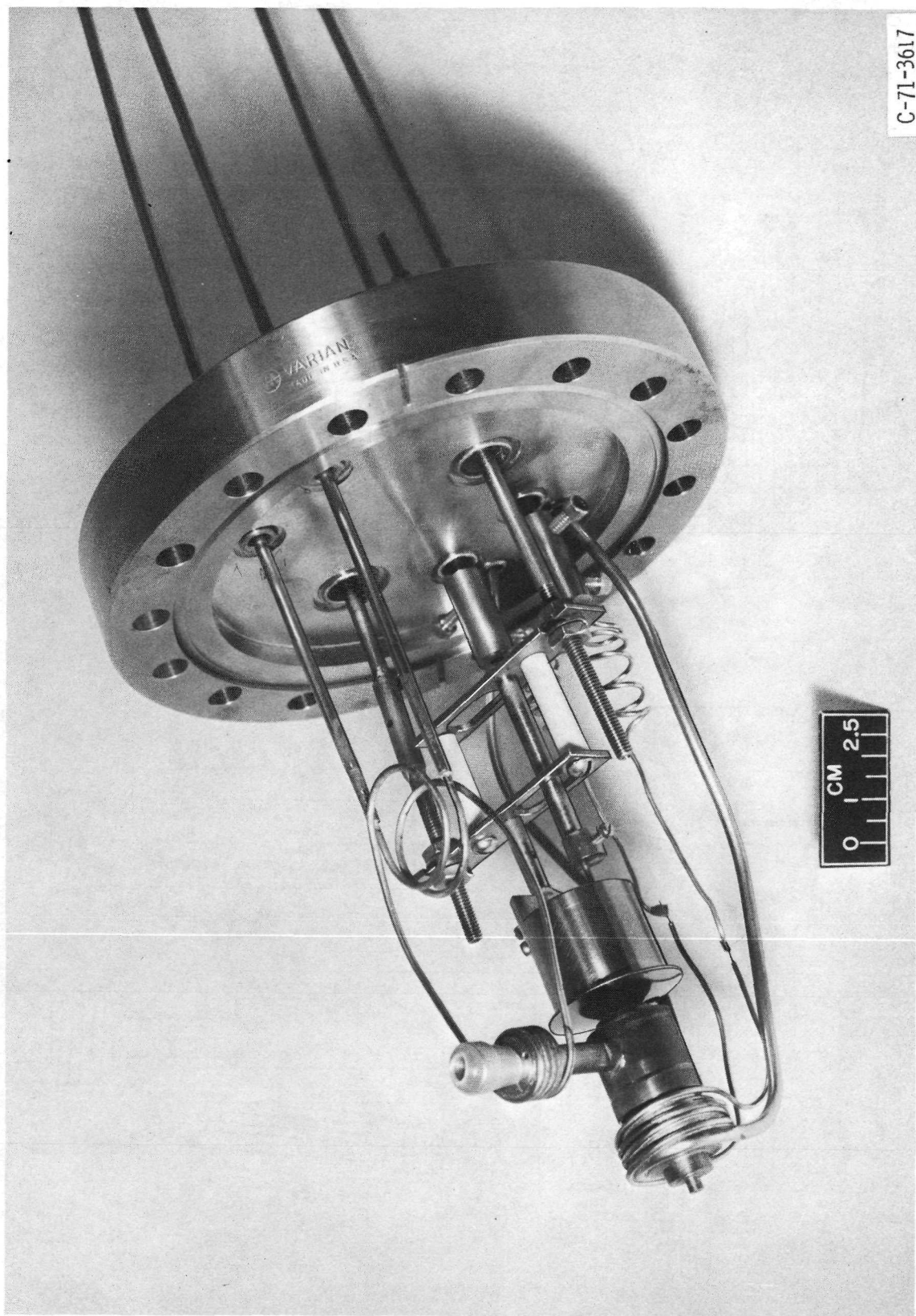


(a) Fixed-gap design.



(b) Variable-gap design.

Figure 1 - Diminiode.



(c) Diminiode on vacuum-flange base.

Figure 1. - Concluded.

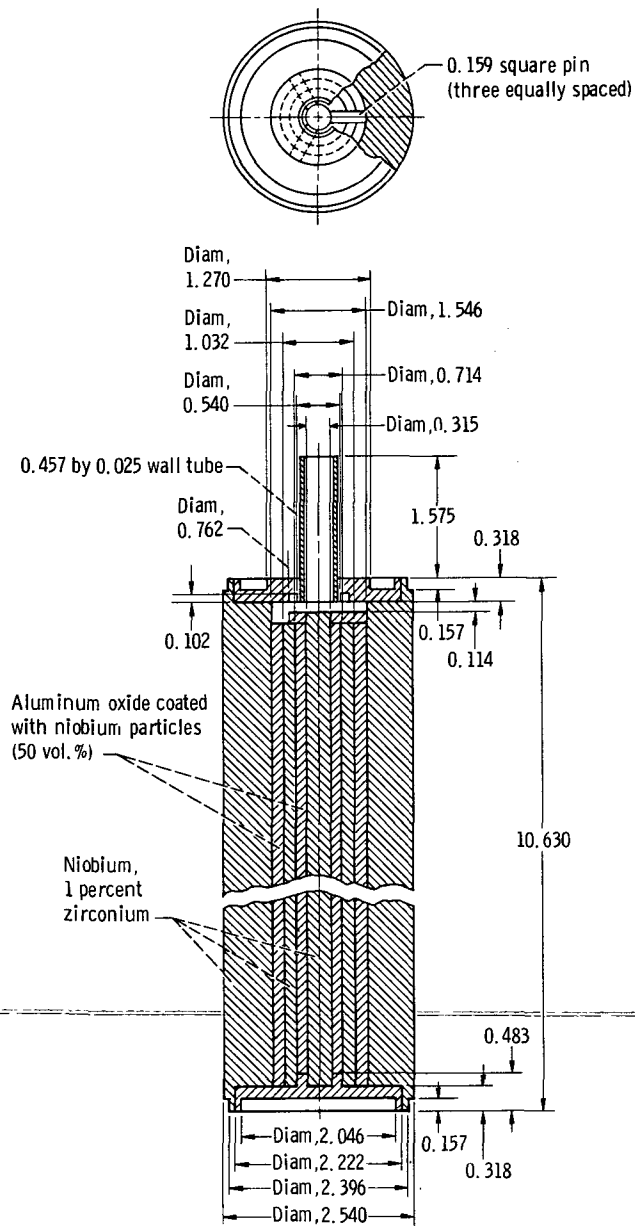
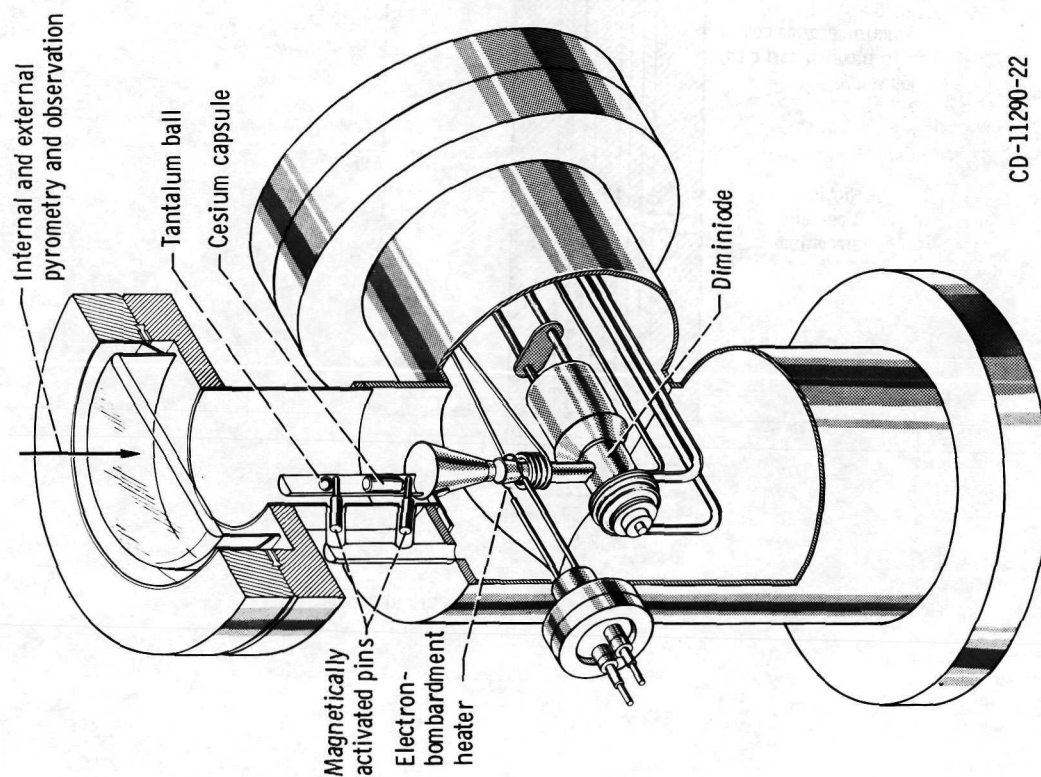
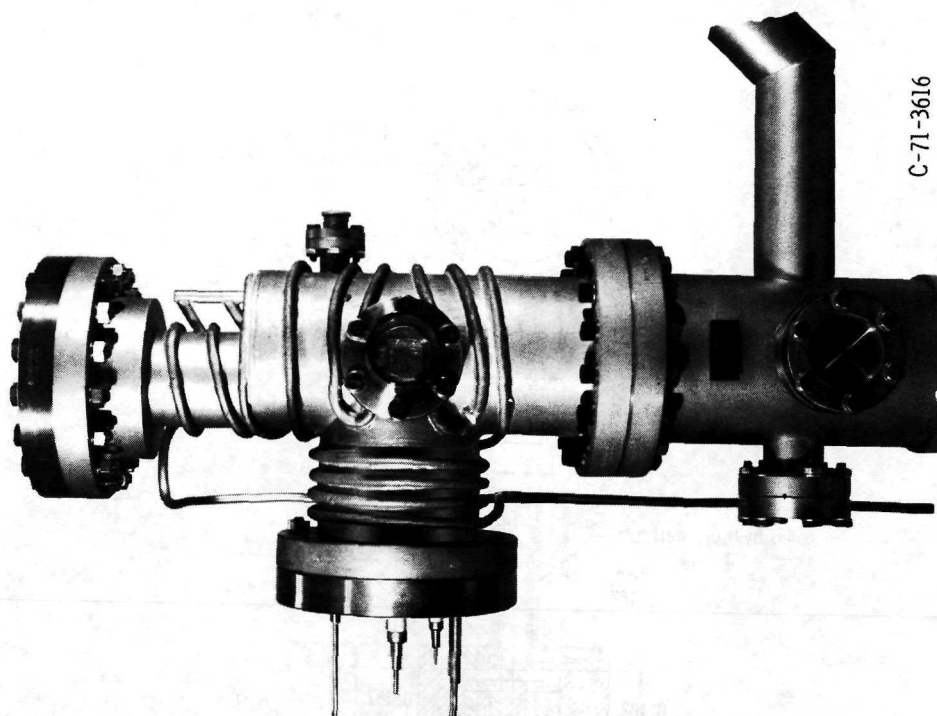


Figure 2. - Cermet assembly for autoclaving. (Dimensions are in centimeters.)



(a) Cutaway view.



(b) Outside view.

Figure 3. - Diminiode vacuum processing chamber (bake-out, calibration, cesium loading, and brazed closure).

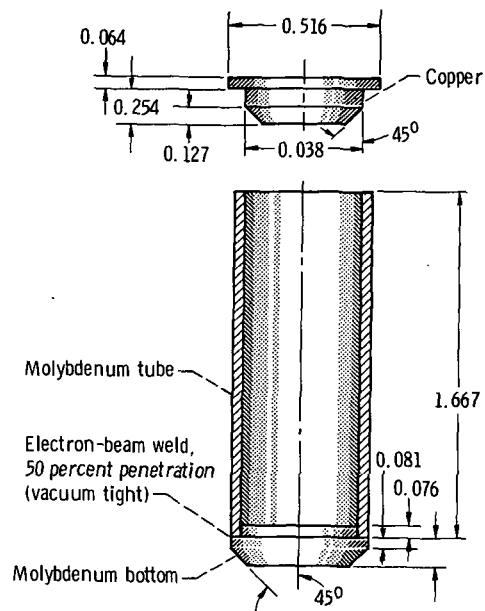
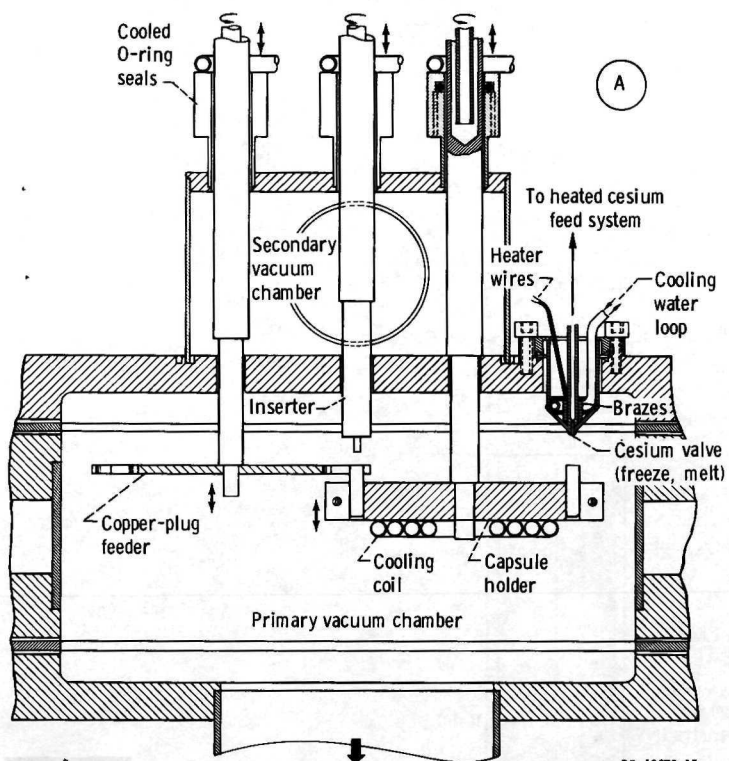
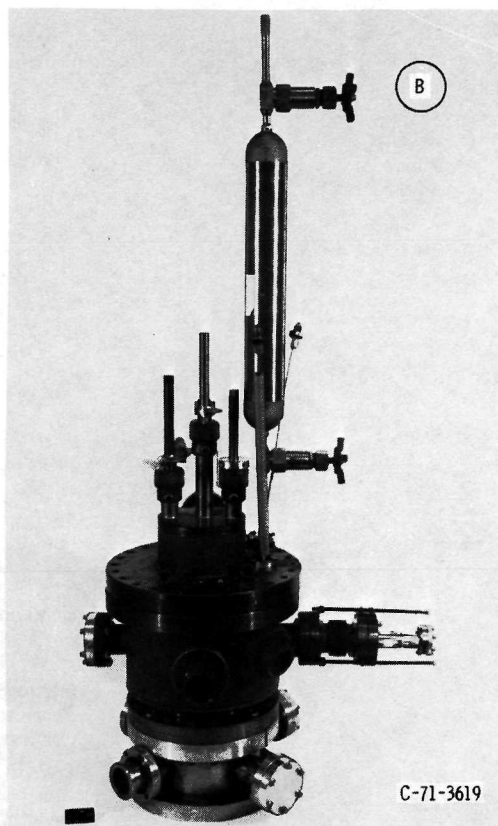


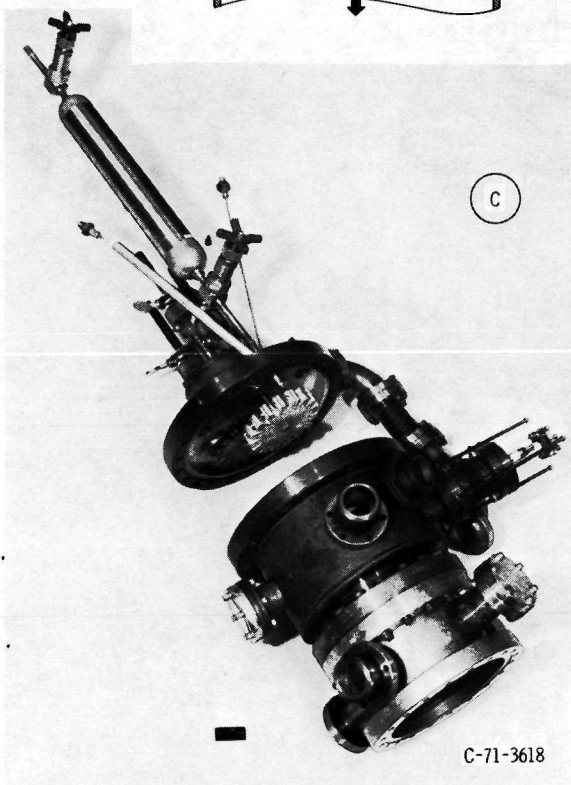
Figure 4. - Cesium capsule. (Dimensions are in centimeters.)
(From ref. 15.)



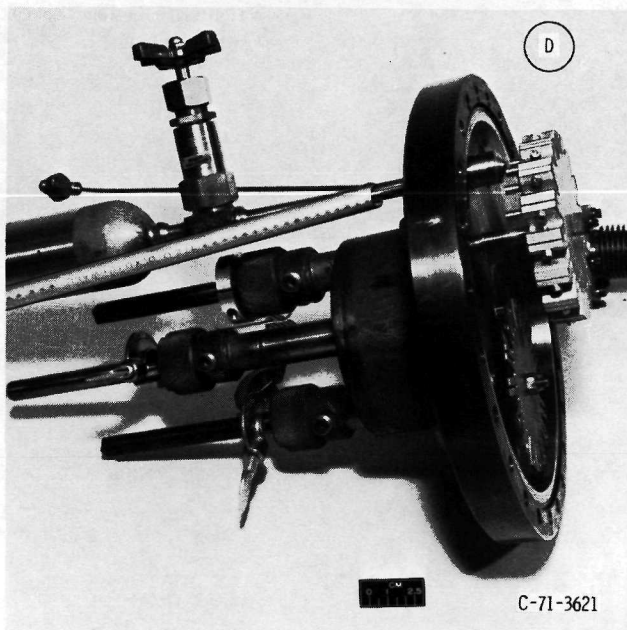
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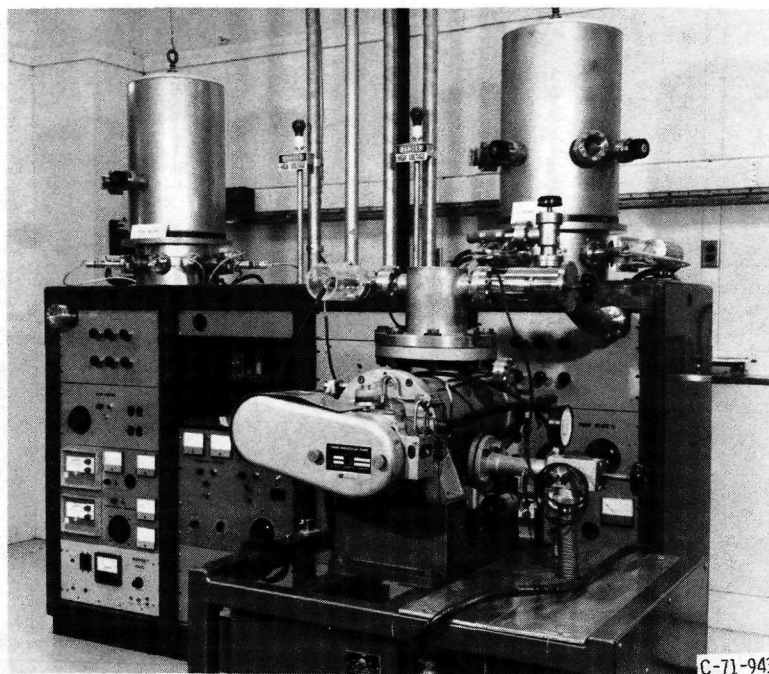


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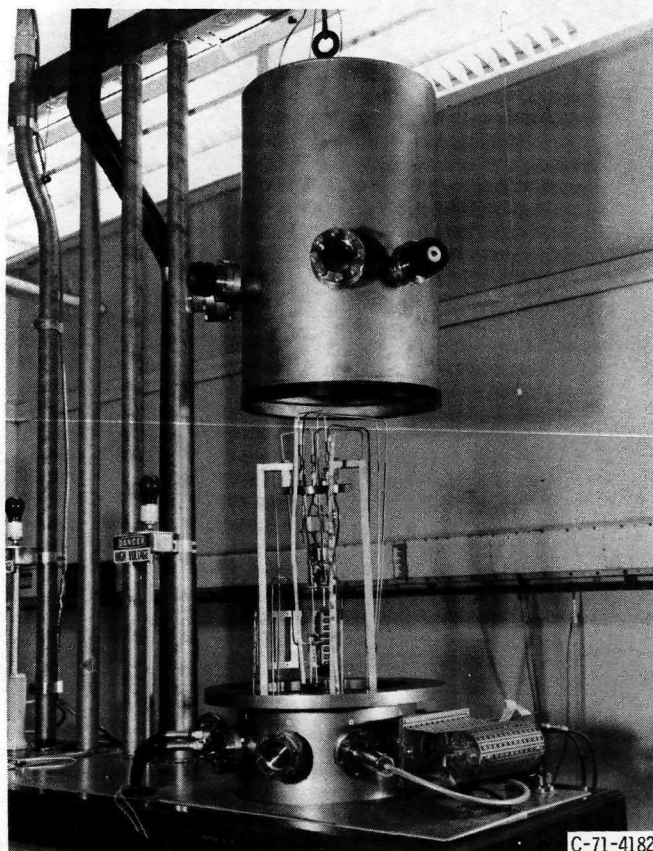


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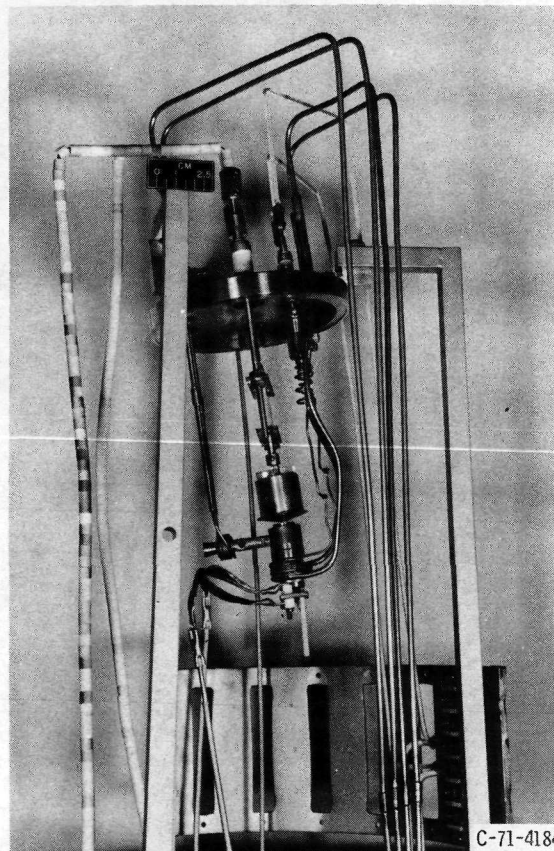
Figure 5. - Station for vacuum packaging cesium (from ref. 15).



(a) Two stands, one being pumped down.



(b) Diminodiode mounted for testing.



(c) Closeup of diminodiode mounted for testing.

Figure 6. - Test stands for thermionic diodes.



Figure 7. - Facility for computer-controlled testing of thermionic diodes.

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